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U.S. ARMY
AVRADCOM

FLIGHT EVALUATION
J-TEC VT-1003 VECTOR AIRSPEED SENSING SYSTEM

FINAL REPORT

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MAY 1977

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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The J-TEC VT-1003 vector airspeed sensing system was evaluated on an AH-1G helicopter in April 1976 by the United States Army Aviation Engineering Flight Activity at Edwards Air Force Base, California. The sensor was mounted above the main rotor plane of rotation throughout the evaluation. All tests were flown at approximately 8000 pounds gross weight, mid center of gravity, and a main rotor speed of 324 rpm. The linear calibrations provided for in the system were unacceptable above 50 knots true airspeed (KTAS) and nonlinear post-processing was required. Using the nonlinear calibrations, longitudinal errors above a skid height of 50 feet in forward flight above 10 KTAS were less than 3 knots. Errors were less than 6 knots between 10 KTAS forward and 30 KTAS rearward.

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INTRODUCTION

BACKGROUND

1. Standard aircraft pitot-static airspeed systems are inadequate for low forward airspeed (below 40 knots) sensing in helicopters, and are inoperable in crosswind and downwind flight conditions. The United States Army Avionics Laboratory, Fort Monmouth, New Jersey, is developing a lightweight doppler navigation system (LDNS) which requires inputs from an airspeed system that will operate reliably in the low-speed nap-of-the-earth (NOE) flight regime. The United States Army Aviation Engineering Flight Activity (USAAEFA) had previously tested an experimental low-airspeed system manufactured by J-TEC, Inc. (ref 1, app A). In May 1975, the United States Army Aviation Systems Command (AVSCOM)* directed USAAEFA to evaluate two low-airspeed systems for the Avionics Laboratory (ref 2) and a test plan was prepared by USAAEFA (ref 3). One of these systems was the J-TEC VT-1003 vector airspeed sensing system.

TEST OBJECTIVES

2. The objective of this evaluation was to define the operating characteristics of the J-TEC airspeed system in an NOE flight environment. Specific objectives were to define:

a. Effective airspeed range for the system.

b. Impact of flight direction on system accuracy.

c. Suitability of the cockpit display.

DESCRIPTION

3. The VT-1003 vector airspeed sensing system is manufactured by J-TEC Associates, Inc. of Cedar Rapids, Iowa. It consists of a sensor head, an electronic processor, and an airspeed and direction indicator. The sensor has an outside diameter of approximately 10-1/2 inches, weighs approximately 3-1/2 pounds, and has six tubes radially mounted on a 5-3/8 inch diameter hub. As air flows through the tubes, the velocity in each tube is measured by an ultrasonic transducer. True airspeed is measured directly with no correction required for temperature or altitude, and the electronic processor resolves the sensor outputs into lateral and longitudinal true airspeed. The theory of operation and a more detailed description of the system are provided in appendix B.

*Since redesignated Army Aviation Research and Development Command (AVRADCOM).

4. The cross-pointer indicator shown in appendix B has a fixed display in the form of concentric circles 10 knots apart with zero located at the geometric center and 50 knots at the outer ring. The horizontal pointer moves up with increasing forward airspeed; the vertical pointer moves in the direction of lateral aircraft motion. The intersection of the two pointers indicates resultant vector airspeed.

5. The sensor was mounted above the main rotor hub on a 13-inch extension to a standpipe placed inside the hollow main rotor shaft. The installation placed the sensor above the main rotor plane of rotation. The aircraft used in this evaluation was an AH-1G, SN 67-15844. A detailed description of the aircraft is contained in the operator's manual (ref 4, app A).

TEST SCOPE

6. The J-TEC system was evaluated in April 1976 at Edwards Air Force Base, California. The J-TEC system was flown for a total of 13 hours, of which 8 hours were productive. Flight conditions were within the limitations imposed by the safety-of-flight release (ref 5, app A) and the operator's manual. Longitudinal airspeeds tested were from 30 knots true airspeed (KTAS) rearward to 130 KTAS forward; lateral airspeeds were from 40 KTAS left to 40 KTAS right. Various azimuths were tested, and the effects of angle of attack (rates of climb and descent) were investigated.

TEST METHODOLOGY

7. The J-TEC system was tested to 40 KTAS near the ground, using a calibrated pace vehicle as an airspeed reference. Wind speed and direction were measured and added vectorially to the pace vehicle speed to obtain aircraft true airspeed.

8. High-speed tests were conducted using a calibrated pitot-static system on a test boom as a reference. True airspeed was calculated by correcting calibrated airspeed for air density effects. Angle of attack and sideslip vanes were mounted on the test boom and were used to determine the effects of those parameters on the J-TEC system.

9. The system provided component airspeed signals to the cockpit indicator, which displayed total airspeed and sideslip angle. However, the system provided the longitudinal and lateral velocity measurements in volts to the test data recorder, and it was necessary to obtain a system calibration to calculate true airspeeds. A curve fit was used on both the longitudinal and lateral components to relate output voltage to true airspeed. System errors were obtained by subtracting the longitudinal and lateral true airspeeds from the results of the curve-fit equations.

10. Previous testing on other low-airspeed systems (refs 1 and 6 through 10, app A) indicated that optimal results would be obtained by mounting the sensor on a standpipe above the main rotor mast. This was the only configuration evaluated.

RESULTS AND DISCUSSIO

GENERAL

11. The J-TEC VT-1003 sensor was mounted above the main rotor plane of rotation throughout the evaluation. All tests were flown at approximately 8000 pounds gross weight, mid center of gravity (cg), and a main rotor speed of 324 rpm. The linear calibrations provided for in the system were unacceptable above 50 KTAS, and nonlinear post-processing was required. Using the nonlinear calibrations, longitudinal errors above a skid height of 50 feet in forward flight above 10 KTAS were less than 3 knots. Errors were less than 6 knots between 10 KTAS forward and 30 KTAS rearward.

SYSTEM CALIBRATION

12. The system provided a voltage output which had to be calibrated for both axes. The calibration data are shown in figures 1 and 2, appendix D. Since the cockpit indicator supplied with the system used a linear knots/volts relationship, a zero intercept linear curve-fit calibration was determined, with the following results:

Longitudinal airspeed in knots = 16.66 (V_x)

S = 7.0

Lateral airspeed in knots = 17.02 (V_y)

S = 2.9

Where:

V_x and V_y are the longitudinal and lateral system outputs in volts, and

S is the standard error of estimate

The linear calibration was satisfactory for sideward and rearward airspeeds and in forward flight to 50 KTAS, as shown in figures 3 and 4, appendix D. However, at airspeeds above 50 KTAS, the errors were excessive.

13. Third-degree polynomial curve fits were used to improve on the results of the linear equations. These fairings are shown in figures 1 and 2, appendix D, and are represented by the following equations:

$$\text{Longitudinal airspeed in knots} = 1.002602 + 15.12141\,(V_x) + 0.7320859\,(V_x)^2 + 0.01057883\,(V_x)^3$$

$S = 2.9$

$$\text{Lateral airspeed in knots} = 0.6045308 + 13.64699\,(V_y) - 0.4400179\,(V_y)^2 + 0.7359905\,(V_y)^3$$

$S = 2.0$

These equations were used to present the J-TEC data in figures 5 through 8, appendix D. Provisions should be made for a nonlinear calibration within the system.

SYSTEM PERFORMANCE IN FORWARD AND REARWARD FLIGHT

14. The corrected system performance in forward and rearward flight is shown in figure 5, appendix D. Longitudinal airspeed errors above a skid height of 50 feet in forward flight between 10 and 130 KTAS were below 3 knots. Between 10 KTAS forward and 30 KTAS rearward, the magnitude of the errors increased to approximately 6 knots above the skid height of 50 feet and up to 10 knots at a skid height of 5 feet. The longitudinal errors at a skid height of 5 feet were excessive and should be corrected. The lateral errors in forward and rearward flight were less than 3 knots throughout the airspeed range tested for all skid heights.

SYSTEM PERFORMANCE IN LATERAL FLIGHT

15. System performance in sideward flight is shown in figure 6, appendix D. Sideward flight error trends were similar to those found in forward and rearward flight. The longitudinal error was generally greater than the lateral error in both flight regimes. However, in lateral flight, system performance was not influenced by ground effect in either the longitudinal or lateral airspeed outputs.

16. The greater accuracy in the lateral axis compared to the longitudinal axis may be caused by the mounting geometry of the sensor. Tubes 1 and 4 (app B) were positioned directly along the lateral axis of the aircraft, allowing lateral airspeed to be calculated using either one or two tube outputs; calculating the longitudinal airspeed component always required two tubes. The equations used to calculate longitudinal and lateral airspeeds, depending on direction of relative wind, are shown in table 1 of appendix B.

SIDESLIP AND ANGLE OF ATTACK EFFECTS

17. The effects of the relative wind direction (sideslip) are shown in figure 7, appendix D. At airspeeds below 54 KTAS, longitudinal and lateral errors with sideslip were consistent with the errors in longitudinal flight.

18. From 54 KTAS, a trend develops with increasing airspeed in which the longitudinal output diminishes with increasing sideslip in either direction, and the lateral error is to the right in left sideslip and to the left in right sideslip. This trend is more pronounced at 108 KTAS and should be corrected.

19. The effects of the aircraft angle of attack on system performance are shown in figure 8, appendix D. The flight test data indicate very small effects with fuselage angles of attack to 22 degrees in climb (negative angle of attack). At the two airspeeds tested, the longitudinal position error increased with increasing angles of attack. The largest longitudinal error was 20 KTAS at 54 KTAS and an angle of attack of +17 degrees (1800 feet per minute descent), and should be corrected. Lateral airspeed errors were similar for both airspeeds and were less than 4 KTAS for all angles of attack tested.

COCKPIT DISPLAY

20. The cockpit indicator was a cross-pointer type (app B) and provided adequate qualitative information to the pilot as to the direction of the relative wind. The resolution of the indicator was inadequate and resultant airspeed magnitude could not accurately be determined. A display showing a numerical value for resultant airspeed should be incorporated.

RELIABILITY AND MAINTAINABILITY

21. The system operated reliably throughout the test. However, additional testing should be done to evaluate performance degradation caused by debris, ice, rain, and temperature extremes.

CONCLUSIONS

22. The linear calibrations provided for in the J-TEC system were unacceptable for airspeeds above 50 KTAS. Nonlinear post-processing was required above 50 KTAS and provided more accurate results at all airspeeds in both axes (paras 12 and 13).

23. Using the nonlinear calibration, longitudinal errors above a skid height of 50 feet in forward flight above 10 KTAS were less than 3 knots. Errors were less than 6 knots between 10 KTAS forward and 30 KTAS rearward (para 13).

24. Low-airspeed in-ground-effect (IGE) errors were excessive during forward and rearward flight (para 13).

25. Errors during high-speed flight with sideslip were excessive (para 18).

26. Errors during high angles of attack (high rates of descent) were excessive (para 19).

27. The system generally showed smaller errors in the lateral axis than in the longitudinal axis for all horizontal flight azimuths tested (para 16).

28. The cockpit indicator, while giving adequate relative wind direction information, did not have adequate resolution to accurately determine resultant airspeeds (para 20).

RECOMMENDATIONS

29. Provisions should be made for a nonlinear calibration within the system (para 13).

30. Errors should be reduced during the following flight conditions:

 a. Low-speed forward and rearward flight in IGE (para 14).

 b. High-speed flight with sideslip (para 18).

 c. High angle of attack (high rate of descent) (para 19).

31. A display to the indicator showing a numerical value for resultant airspeed should be incorporated (para 20).

32. Additional testing should be conducted to evaluate performance degradation caused by debris, ice, rain, and temperature extremes (para 21).

APPENDIX A. REFERENCES

1. Final Report IV, US Army Aviation Systems Test Activity (USAASTA), Project No. 71-30, *Flight Evaluation, J-TEC Airspeed System, Low Airspeed Sensor,* April 1974.

2. Letter, AVSCOM, AMSAV-EQI, 12 May 1975, subject: AVSCOM Test Request No. 75-17, Flight Evaluation of Two Low Airspeed Sensing Systems.

3. Test Plan, USAAEFA, Project No. 75-17, *Flight Evaluation of Two Low Airspeed Sensing Systems,* September 1975.

4. Technical Manual, TM 55-1520-221-10, *Operator's Manual, Army Model AH-1G Helicopter,* April 1969.

5. Letter, AVSCOM, DRSAV-EQA, 23 March 1976, subject: Safety-of-Flight Release for J-TEC Low Speed System Installed on AH-1.

6. Final Report I, USAASTA, Project No. 71-30, *Flight Evaluation, Elliott Low Airspeed System,* September 1972.

7. Final Report II, USAASTA, Project No. 71-30, *Flight Evaluation, Aeroflex True Airspeed Vector System, Low Airspeed System,* March 1974.

8. Final Report III, USAASTA, Project No. 71-30, *Flight Evaluation, Pacer Systems, Inc., LORAS II Low Airspeed System,* March 1974.

9. Final Report V, USAAEFA, Project No. 71-30, *Flight Evaluation, Rosemount Orthogonal Low Airspeed System, Low Airspeed Sensor,* November 1974.

10. Final Report VI, USAAEFA, Project No. 71-30, *Flight Evaluation, Elliott Dual-Axis Low Airspeed System, LASSIE II, Low Airspeed Sensor,* September 1975.

APPENDIX B. SYSTEM DESCRIPTION AND THEORY OF OPERATION

INTRODUCTION

1. The J-TEC model VT-1003 vector ai speed sensing system measures relative wind speed and direction with no moving parts. The VT-1003 consists of a sensor head, an electronic processor, and an airspeed and direction indicator. The components are shown in photo 1. During this evaluation, the sensor was mounted on a 13-inch standpipe extension over the main rotor mast. The sensor installation is shown in photo 2.

Sensor

2. The sensor head consists of six identical tubes, 2-5/8 inches long, mounted radially on a 5-3/8-inch diameter hub. It is mounted on the aircraft so that one pair of tubes is aligned with the lateral axis of the aircraft and the other tubes are 30 degrees either side of the longitudinal axis. A top view of the sensor head is shown in photo 3. The sensor weighs approximately 3-1/2 pounds.

3. Air velocity in any tube is related to the total velocity vector by the following equation.

$$V = V_{tot} \cos \theta \qquad (1)$$

Where:

V = Velocity through a tube

V_{tot} = Total velocity vector

θ = Angle between sensing tube and wind direction

Regardless of wind direction, flow exists in at least two adjacent tubes at any time, allowing two equations in the form of equation 1 to be solved simultaneously for the two unknowns.

4. At the inboard end of each tube, near the hub, is a vortex strut (a wire of known diameter) located just ahead of an ultrasonic transducer. As air moves through the tube past the strut, a series of alternating vortices is created. The frequency of these vortices is directly proportional to true air velocity, and is independent of density. The vortices pass through an ultrasonic beam transmitter, modulating it. The modulation frequency is detected and is sent to its receiver where it is converted to an audio frequency signal.

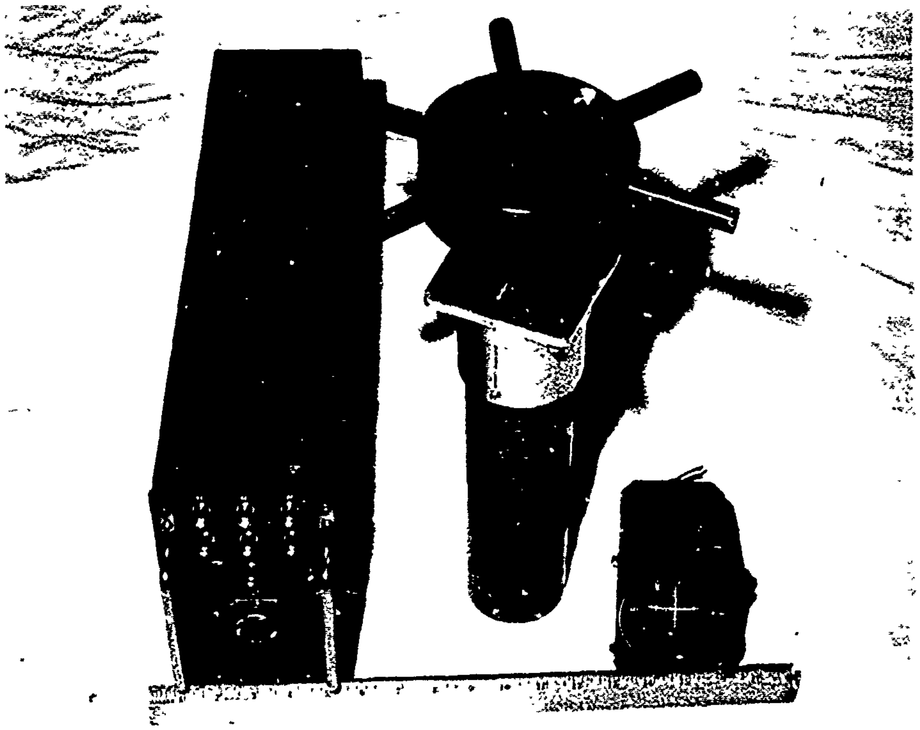

Photo 1. J-TEC VT-1003 Components.

Photo 2. Sensor Installation.

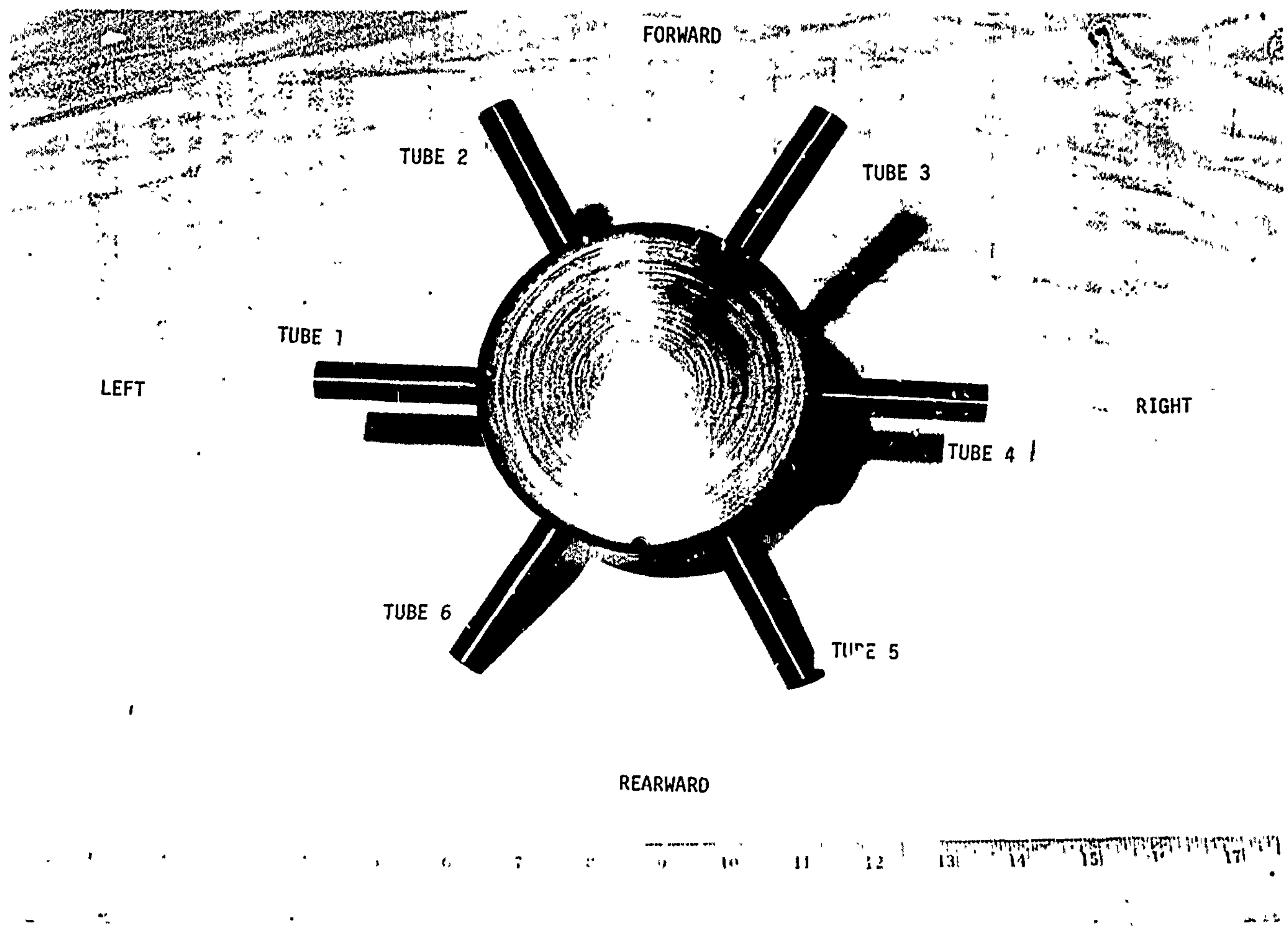

Photo 3. Sensor Head.

Electronic Processor

5. The electronic processor and its case, a box 5-inches wide by 8-inches high by 20-inches long, weighs 7 pounds. It converts the input audio frequency signals from the sensor to voltages, and determines which two adjacent tubes have the greatest velocities. The processor outputs two voltages proportional to longitudinal and lateral true airspeed. Typically, the calibration is approximately 50 mv/knot. Airspeeds are calculated within the processor according to one of the sets of equations in table 1.

Table 1. Component Airspeed Computations.

Tubes Used	Longitudinal Airspeed (V_x)	Lateral Airspeed (V_y)
1 and 2	$0.577\ (V_2 - V_1)$	$-V_1$
2 and 3	$0.577\ (V_2 + V_3)$	$V_3 - V_2$
3 and 4	$0.577\ (2V_3 - V_4)$	V_4
4 and 5	$-0.577\ (2V_5 - V_4)$	V_4
5 and 6	$-0.577\ (V_5 - V_6)$	$V_5 - V_6$
6 and 1	$-0.577\ (2V_6 - V_1)$	$-V_1$

Cockpit Indicator

6. The cross-pointer indicator shown in photo 1 has a fixed display in the form of concentric circles 10 knots apart with zero located at the geometric center and 50 knots at the outer ring. The horizontal pointer moves up with increasing forward airspeed; the vertical pointer moves in the direction of lateral aircraft motion. The intersection of the two pointers indicates resultant vector airspeed.

APPENDIX C. TEST INSTRUMENTATION

1. The following parameters were recorded by a magnetic tape system on board the test helicopter and were displayed on the pilot instrument panel.

Time of day
Engineer event
Pilot event
Run number
Altitude (boom)
Airspeed (boom)
Altitude (radar)
Outside total temperature
Angle of attack
Angle of sideslip
Rotor speed
Pitch attitude
Roll attitude
Magnetic heading
Fuel-used counter
Fuel temperature
J-TEC longitudinal airspeed
J-TEC lateral airspeed

2. The following parameters were hand-recorded at the ground station.

Wind speed and direction
Pace vehicle speed and direction
Ambient temperature

APPENDIX D. TEST DATA

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FIGURE 1

AIRSPEED CALIBRATION IN FORWARD AND REARWARD FLIGHT

AH-1G USA S/N 67-15644 J-TEC VT-1003 AIRSPEED SYSTEM S/N 0-78-10

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	SKID HEIGHT (FEET)
□	8000.	196.8 (MID)	2600.	18.0	324.	.0043	5.
○	7740.	196.1 (MID)	2280.	9.0	324.	.0041	5.
△	8180.	196.5 (MID)	2360.	12.5	324.	.0043	50.
◇	7960.	196.8 (MID)	2200.	8.0	324.	.0042	50.
⊹	8080.	196.4 (MID)	2640.	18.0	324.	.0043	50.
✕	9270.	193.6 (MID)	4620.	12.5	324.	.0047	OGE

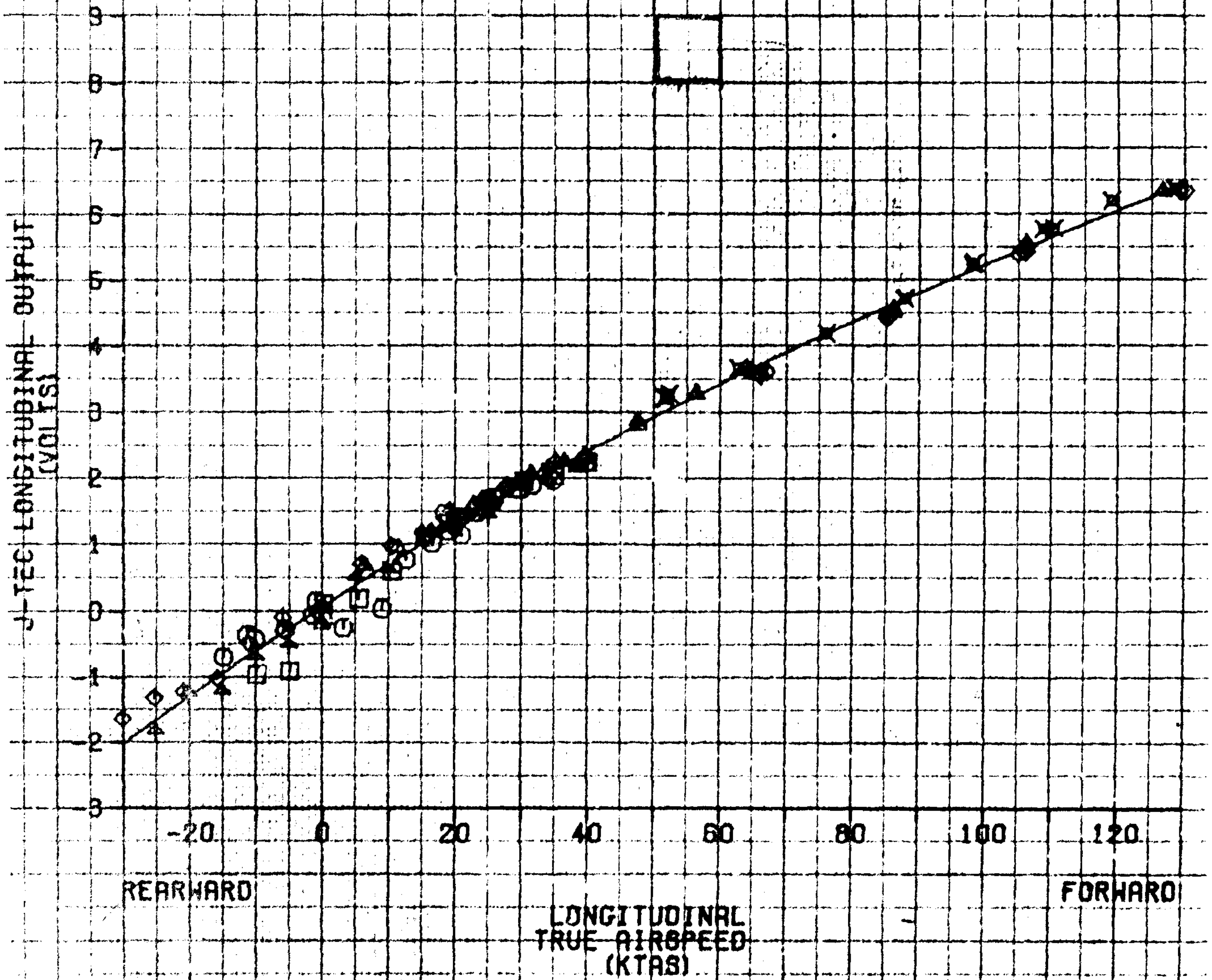

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FIGURE 2

AIRSPEED CALIBRATION IN SIDEWARD FLIGHT

OH-1G USA S/N 67-15844 J-TEC VT-1005 AIRSPEED SYSTEM S/N [illegible]

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	SKID HEIGHT
⊡	7720.	198.1(MID)	2000.	17.5	324.	.0042	5.
⊡	7490.	195.8(MID)	2500.	[illegible]	[illegible]	.0040	5.
◇	7980.	198.[illegible](MID)	[illegible]	[illegible]	[illegible]	.004[illegible]	50.
✝	7950.	198.9(MID)	2900.	16.0	[illegible]	.0045	50.

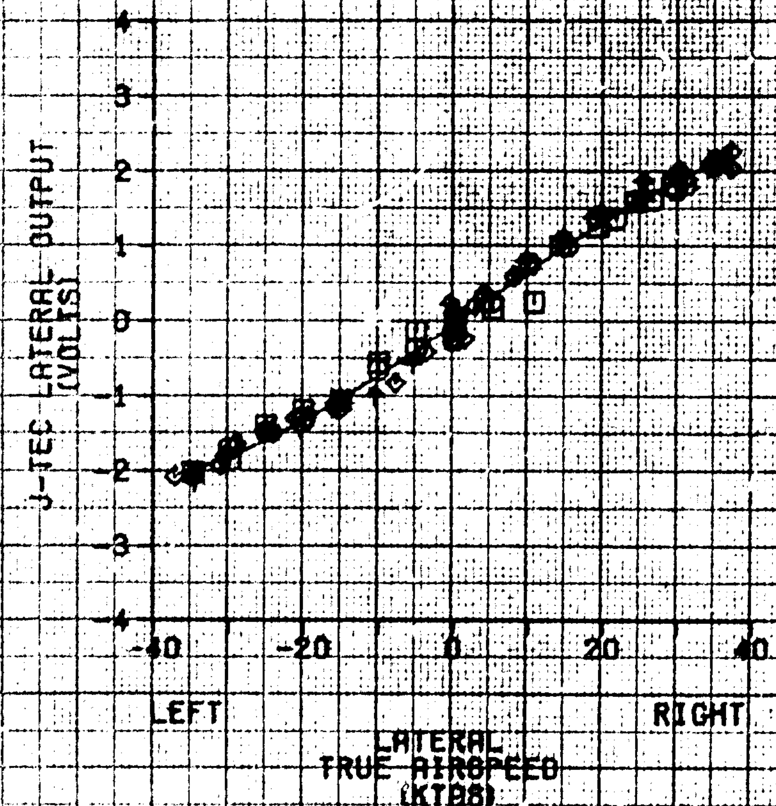

FIGURE 3

LONGITUDINAL SYSTEM PERFORMANCE WITH LINEAR CALIBRATION

AH-1G USA S/N 67-15844 J-TEC VT-1003 AIRSPEED SYSTEM S/N 0-75-10

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	SKID HEIGHT (FEET)
□	8000.	196.3 (MID)	2800.	16.0	324.	.0043	5.
○	7740.	196.1 (MID)	2260.	9.0	324.	.0041	5.
△	8180.	196.5 (MID)	2380.	12.5	324.	.0043	50.
◇	7960.	196.9 (MID)	2200.	8.0	324.	.0042	50.
✦	8030.	196.4 (MID)	2640.	10.0	324.	.0043	50.
✕	8270.	196.0 (MID)	4620.	12.5	324.	.0047	OGE

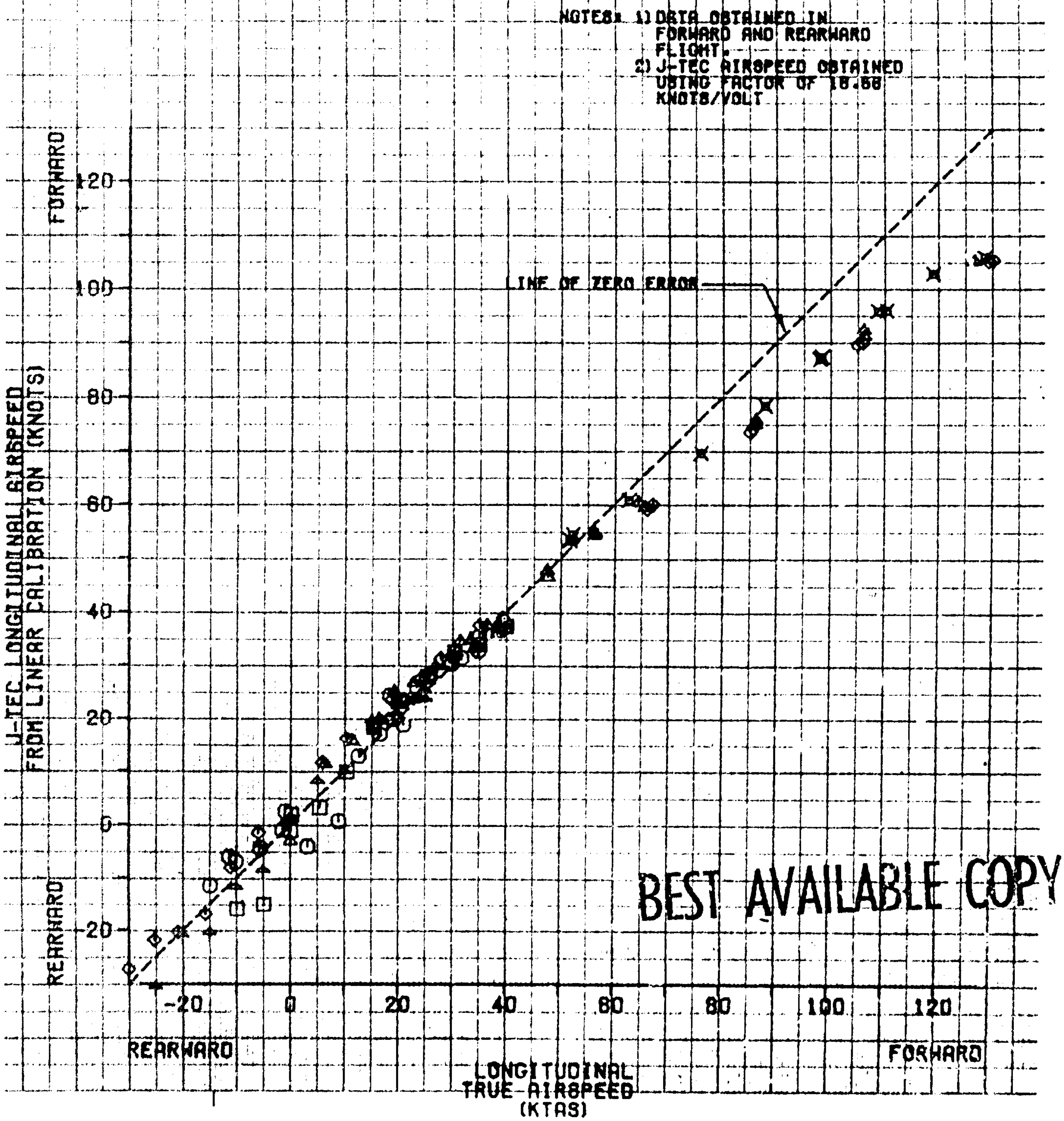

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FIGURE 4

LATERAL SYSTEM PERFORMANCE WITH LINEAR CALIBRATION

AH-1G USA S/N 67-15344 J-TEC VT-1003 AIRSPEED SYSTEM S/N [illegible]

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG C_T	SKID HEIGHT (FEET)
□	7720.	195.1 (MID)	2900.	17.5	324.	.0042	5.
○	7490.	195.6 (MID)	2500.	11.0	324.	.0040	5.
◇	7380.	196.3 (MID)	2340.	9.0	324.	.0042	50.
△	7950.	196.5 (MID)	2900.	16.0	324.	.0043	50.

NOTES: 1) DATA OBTAINED I. SIDEWARD FLIGHT
2) J-TEC AIRSPEED OBTAINED USING FACTOR OF 17.02 KNOTS/VOLT

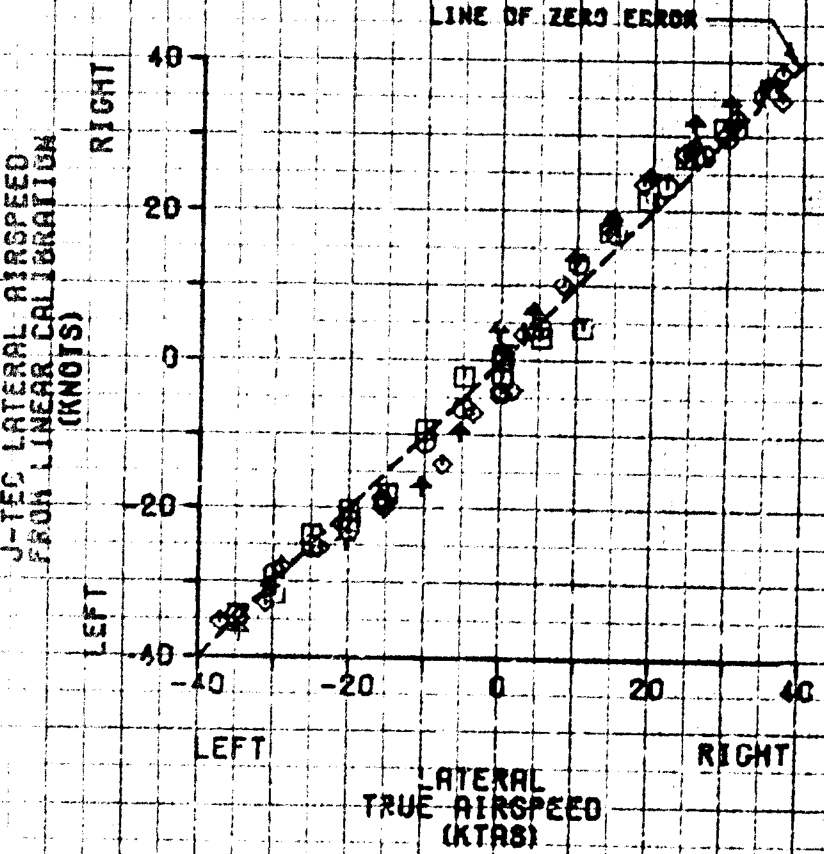

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FIGURE 5

SYSTEM PERFORMANCE IN FORWARD AND REARWARD FLIGHT

AH-1G USA S/N 67-15844 J-TEC VT-1003 AIRSPEED SYSTEM S/N C-75-10

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	SKID HEIGHT (FEET)
□	8000.	198.8 (MID)	2800.	18.0	324.	.0043	5.
○	7740.	198.1 (MID)	2280.	9.0	324.	.004[illegible]	5.
▲	8160.	198.5 (MID)	2350.	12.5	324.	.00[illegible]	50.
◇	7980.	198.8 (MID)	2200.	8.0	324.	.00[illegible]	50.
✝	8080.	198.4 (MID)	2840.	18.0	324.	.0043	50.
✕	8270.	198.8 (MID)	4620.	12.5	324.	.0047	OGE

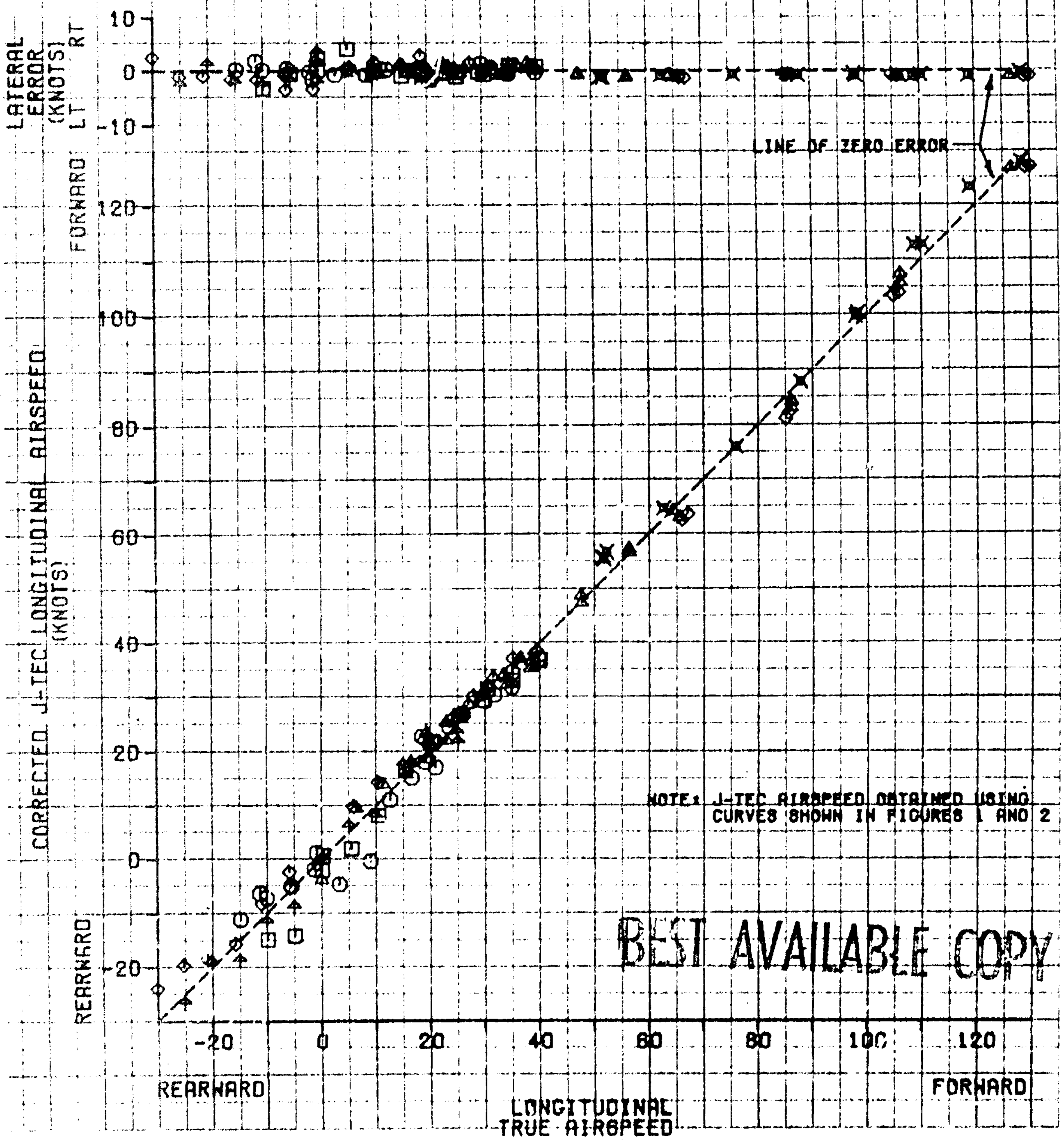


FIGURE 6

SYSTEM PERFORMANCE IN SIDEWARD FLIGHT

AH-1G USA S/N 67-15844

J-TEC VT-1003 AIRSPEED SYSTEM S/N G-75-10

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	SKID HEIGHT (FEET)
□	7720.	198.1 (MID)	2980.	17.5	324.	.0042	5.
○	7490.	195.8 (MID)	2500.	11.0	324.	.0040	5.
◇	7980.	198.8 (MID)	2340.	9.0	324.	.0042	50.
△	7950.	198.8 (MID)	2900.	16.0	324.	.0043	50.

NOTE: J-TEC AIRSPEED OBTAINED USING CURVES SHOWN IN FIGURES 1 AND 2

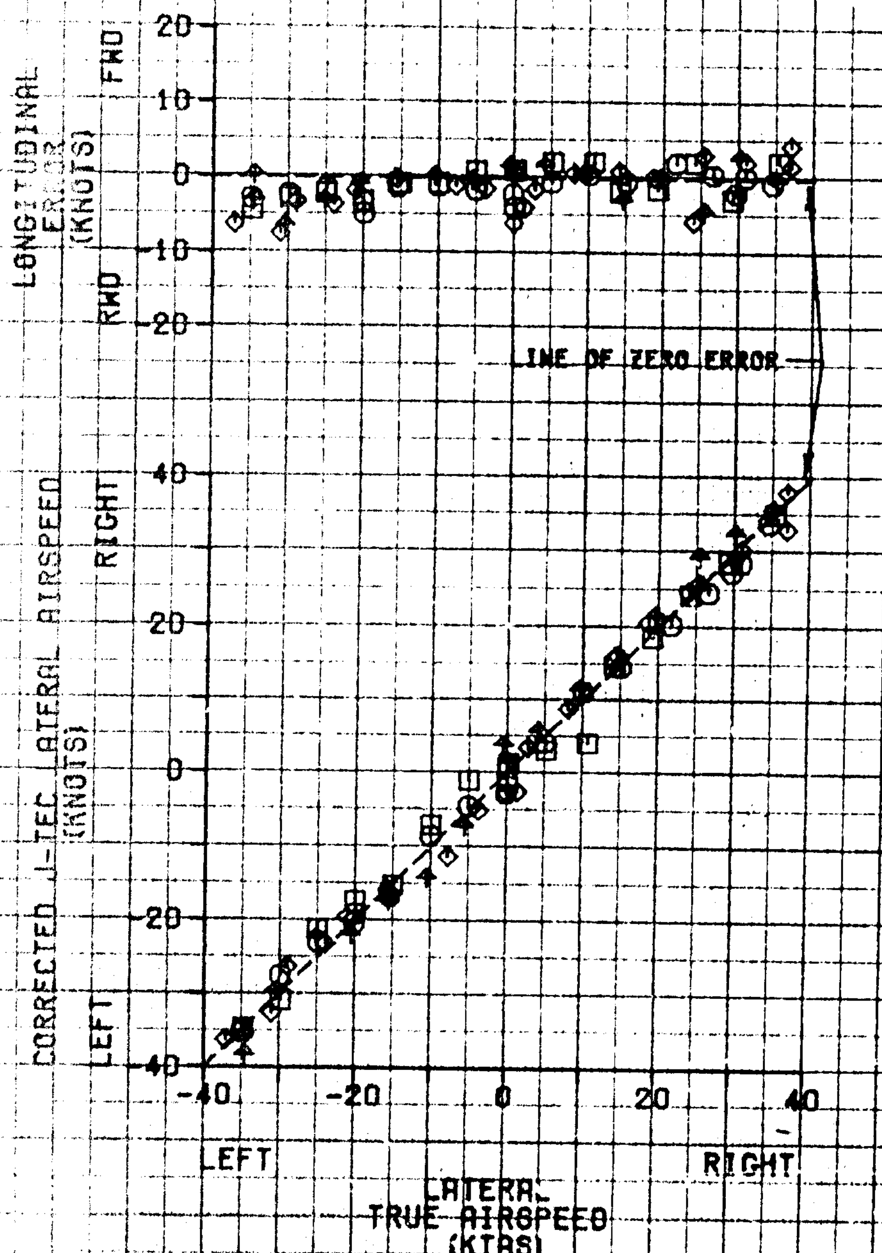


FIGURE 7

SIDESLIP EFFECTS ON SYSTEM ERROR

AH-1G USA S/N 67-15844 J-TEC VT-1003 AIRSPEED SYSTEM S/N G-75-10

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	SKID HEIGHT (FEET)
△	7390.	195.8 (MID)	2820.	16.5	324.	.0040	50.
◇	7600.	196.1 (MID)	4860.	13.0	324.	.0045	OGE

NOTES: 1) SHADED SYMBOLS DENOTE LONGITUDINAL ERROR
2) OPEN SYMBOLS DENOTE LATERAL ERROR
3) J-TEC AIRSPEEDS OBTAINED USING CURVES IN FIG 1 AND 2

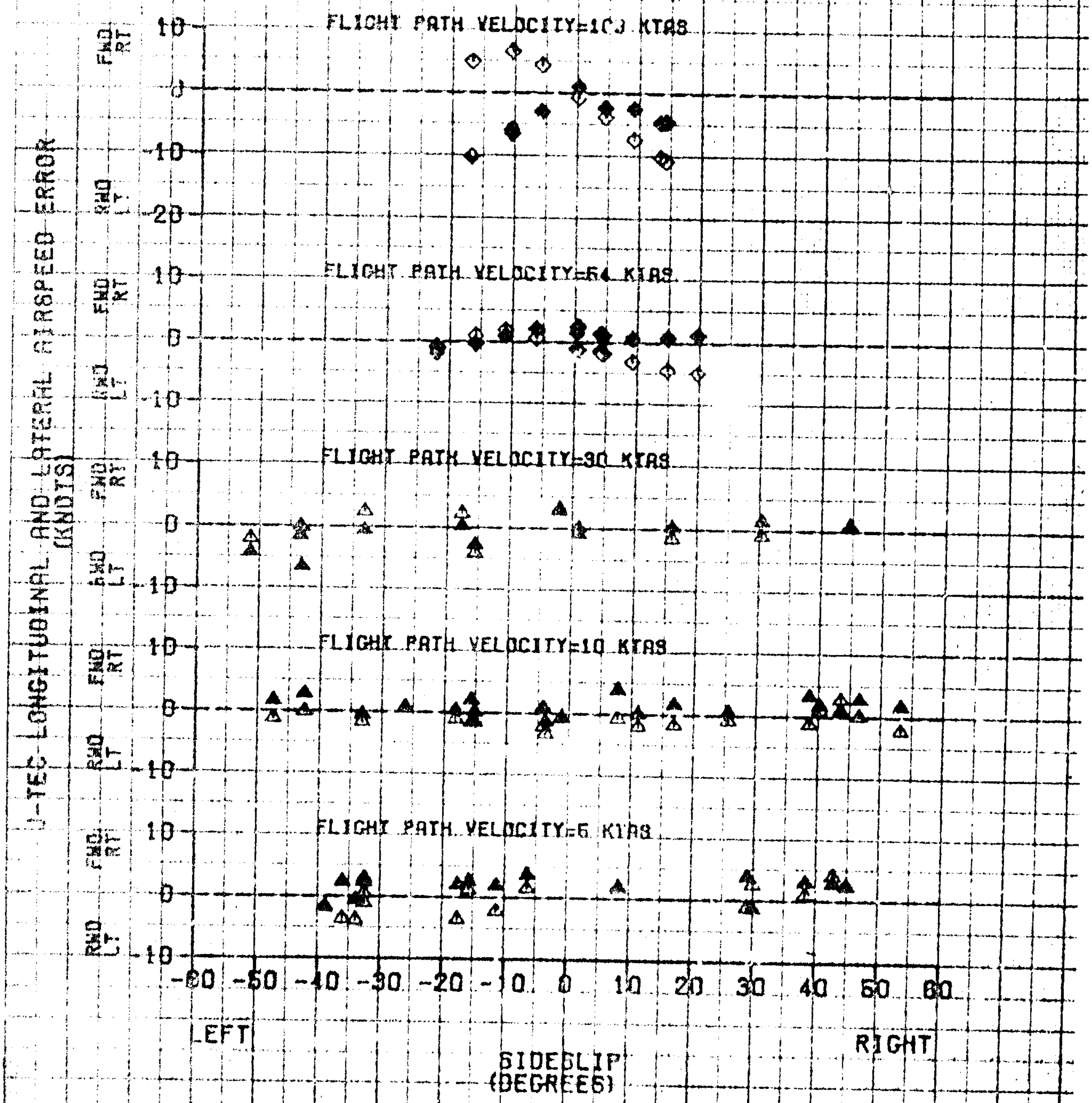


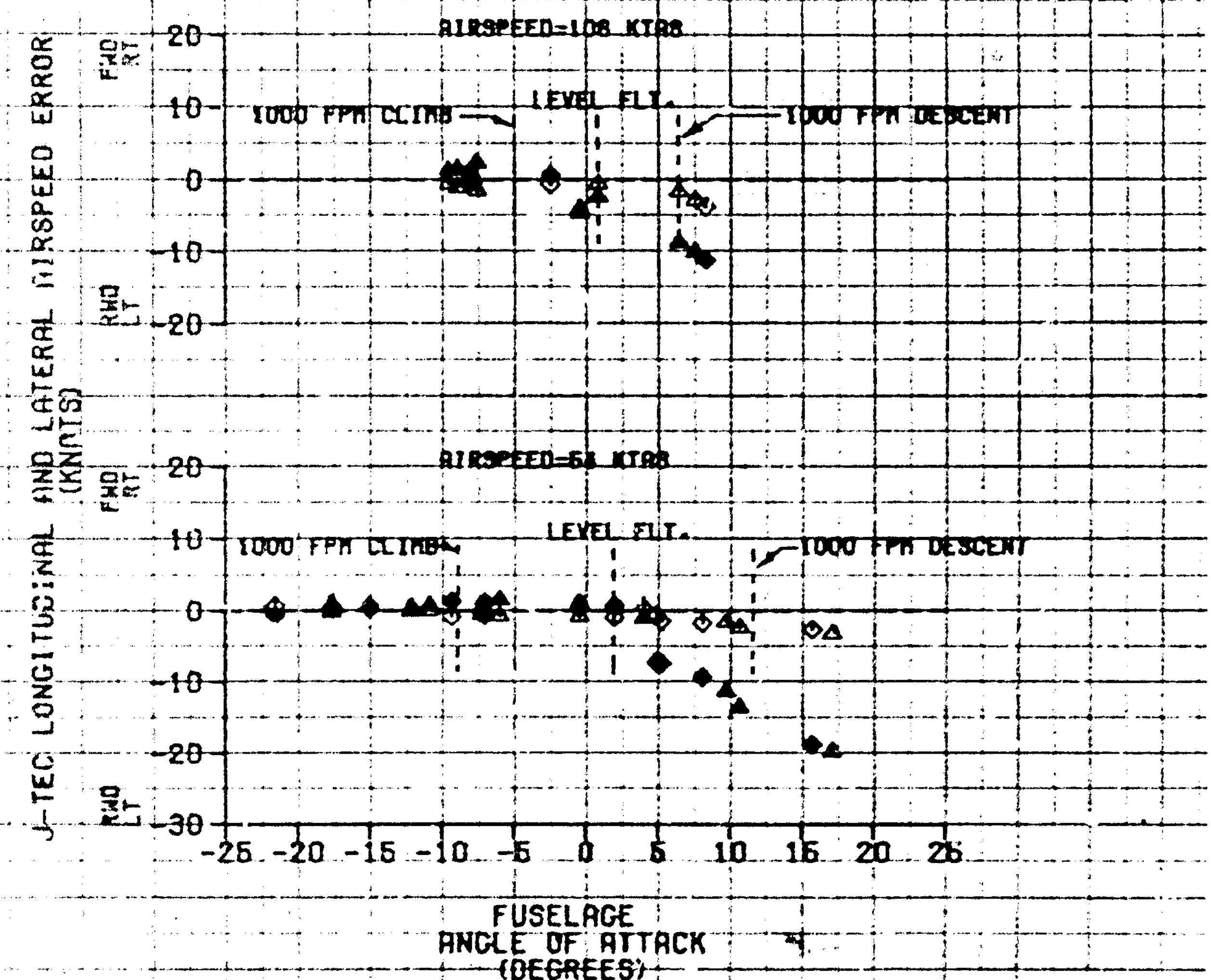
FIGURE 8

ANGLE OF ATTACK EFFECTS ON SYSTEM ERROR

AH-1G USA S/N 67-15844 J-TEC VT-1003 AIRSPEED SYSTEM S/N 0-76-10

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CT	SKID HEIGHT (FEET)
△	8100.	198.4 (MID)	5560.	9.5	324.	.0048	OGE
◇	7950.	198.3 (MID)	5560.	12.5	324.	.0047	OGE

NOTES: 1) SHADED SYMBOLS DENOTE LONGITUDINAL ERROR
2) OPEN SYMBOLS DENOTE LATERAL ERROR
3) J-TEC AIRSPEEDS OBTAINED USING CURVES IN FIG 1 AND 2



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